NASA/DoD Aerospace Knowledge Diffusion Research Project

Paper One:

The Value of Scientific and Technical Information (STI), Its Relationship to Research and Development (R&D), and Its Use by U.S. Aerospace Engineers and Scientists

Paper Presented at the European Forum
"External Information: a Decision Tool"
Strasbourg, France
19 January 1990

Thomas E. Pinelli
NASA Langley Research Center

Rebecca O. Barclay
Rensselaer Polytechnic Institute

Myron Glassman
Old Dominion University

Walter E. Oliu
U.S. Nuclear Regulatory Commission

KNOWLEDGE DIFFUSION INNOVATION NASA DoD AEROSPACE

NASA
National Aeronautics and Space Administration

Department of Defense

INDIANA UNIVERSITY

THE VALUE OF SCIENTIFIC AND TECHNICAL INFORMATION (STI), ITS RELATIONSHIP TO RESEARCH AND DEVELOPMENT (R&D), AND ITS USE BY U.S. AEROSPACE ENGINEERS AND SCIENTISTS

Pinelli, Thomas E.
NASA Langley Research Center, Hampton, Virginia

Barclay, Rebecca O.
Rensselaer Polytechnic Institute, Troy, New York

Glassman, Myron
Old Dominion University, Norfolk, Virginia

Oliu, Walter E.
U. S. Nuclear Regulatory Commission, Washington, DC

Introduction

Viewed as a process, aerospace research and development (R&D) consists of three phases -- idea formulation, problem solving, and invention. It is a process that is inexorably linked to the economic growth, prosperity, and technological progress of modern nations. The collective management and performance of the process affect the innovation and productivity as well as the economic competitiveness and vitality of modern nations.

The nature of science and technology makes scientific and technical information (STI) an important function of the R&D process. The communication or transfer of STI is thus central to the management of R&D activities. As Fischer (1980) points out, "Not only is the communication or transfer of STI an important portion of performing R&D, it is also vital to the dissemination and application of the R&D product."

Embedded in STI are knowledge and ideas that are pursued and transferred by those engineers and scientists engaged in the aerospace R&D process. The fact that, in R&D, knowledge and ideas are frequently embodied in a physical product should not detract from the realization that R&D is first and foremost an information processing and communication activity, and engineers and scientists are information processors who are constantly faced with the problem of effectively and efficiently acquiring and processing STI. How well the objectives of the process are met, and at what cost, depends on a variety of factors, but largely on the ability of engineers and scientists to acquire and process STI and the knowledge and ideas needed to complete the process.

This paper is based on the following four assumptions: (1) STI has value and the value of STI is user based; (2) STI is central and essential to and represents an important function within the R&D process; (3) aerospace R&D is becoming more interdisciplinary in nature and more global and international in scope, thus making the cumulative body of aerospace STI so great that no one engineer or scientist can be acquainted with more than a small portion of the whole; and (4) the potential use, user satisfaction, and efficiency of an aerospace STI system are directly related to the extent to which the information needs, habits, and preferences of aerospace engineers and scientists have been incorporated in the system.

This paper is based on the premise that STI, its use by aerospace engineers and scientists, and the aerospace R&D process are related. We intend to support this premise with data gathered from numerous studies concerned with STI, the relationship of STI to the performance and management of R&D activities, and the information use and seeking behavior of engineers in general and aerospace engineers and scientists in particular. We intend to develop and present a synthesized appreciation of how aerospace R&D managers can improve the efficacy of the R&D process by understanding the role and value of STI in this process.

The Value of Information

To help frame a discussion of information and value, it is helpful to first understand that engineers are not scientists. Despite certain similarities, the two groups are fundamentally different. The difference stems from two primary considerations: (1) the independent nature of science and technology (Allen, 1977; Shapley and Roy, 1985) and (2) the social enculturation of engineers and scientists (Allen, 1977; Krulee and Nadler, 1960; Holmfeld, 1970). The primary difference between engineers and scientists leads not only to different information-seeking practices and habits, but also to differences in the use and value that the two groups place on information (Joenk, 1985).

According to King, et al., (1982), the published literature addressing the value of information, information systems, and information products and services falls into the following two categories:

1. That which describes the concept of value and approaches to measuring value, and
2. That which describes the actual application of the measures of information products and services.

There are enormous problems associated with the notion of information and value such that we cannot begin to resolve in this paper. The reason for this lies in the lack of consensus concerning the notion of value itself. Value is an attribute; it does not exist on its own and can be applied to almost any entity. Value has the following characteristics: (1) it is subjective; (2) value can be assessed by individuals, groups of individuals, organizations, and societies; (3) value is situational and varies over time; and (4) value can be either positive or negative.

Information is both content and package. In discussing the value of information, it is important to distinguish between two things: the **information content** and **information resources**. Content is the **meaning**. It is that part of information that informs, influences, prompts an action, or influences an outcome. Resources are the **services** and the **technologies** used to generate, store, organize, move, and display the package. Resource management, while it does not shape content, does influence the usefulness or value of the message.

Several approaches, largely economic, have been applied to determining the value of information. Among them are included "cost" and "price" as measures of value. The predominant approach to value measurement is based on the "willingness-to-pay" concept, which is an extension of the value-price relationship (King, et al., 1982). A second approach to assessing measuring value, as proposed by Taylor (1986), considers the **use** of an item or product.

According to Taylor (1986),

> The value of information has meaning only in the context of its usefulness to users. There is no way of analyzing value of information except by reference to the environment of those who are its intended clientele.

Taylor's (1986) Value-Added Processes in Information Systems treatise views information resources and services (e.g., libraries, abstracting and indexing services, information analysis, and on-line retrieval systems) as a series of **value-adding processes,** the results of which inform or influence the user, prompt the user to take an action, or influence the outcome of a decision made by the user. He stresses the importance of the clientele or user as "an important element in describing the environment and, hence, a determinant of system design." Stated another way, different classes of professionals need and use information in different ways and have differing interpretations of information, its delivery, utility, structure, and value.

Researchers have used a variety of approaches to measure the value of information and information services. A study by the National Academy of Sciences (1970) suggested that the value of information is determinable from what users are willing to pay for it. In that study, it was proposed that one way to assess the value of information was to look at it from the perspective of users and that users themselves are the best judges of the value of information. They did not directly ask users what they thought the value of information was, but rather they looked at what price users would be willing to pay for information as a means of assessing the value of information.

Mason and Sassone (1978) used an economic modeling approach to measure the value of information service centers and the potential and actual users of such services. Their model assumes that potential users have access to several sources for obtaining information of equivalent quality and are motivated solely by economic efficiency or a "willingness-to-pay" for information. The "willingness-to-pay" approach, combined with the time saved by researchers as a result of their use of information services, was used by Berg (1972). The application of cost benefit analysis to measuring the value of information and information services was discussed by Flowerdew and Whitehead (n/d) and has been applied by Hawgood and Morley (1969), Wolfe (1972), and Wills and Oldman (1977).

King, et al., (1982) assert that the value of information services can be measured from the viewpoint of several participants in the information transfer process, including searchers of secondary information services, readers of primary information products and services, the organizations that fund users, and all of society that is the ultimate beneficiary of a particular kind of information and information service. This approach to determining the value of information was applied to the U.S. Department of Energy's Energy Database (King, et al., 1982) and the U.S. Defense Technical Information Center's Products and Services (Roderer, et al., 1983). This approach assumes two kinds of value -- what the consumer is willing to pay and value derived from the use of information. Both perspectives depend to a large degree on the extent and purposes of use of information.

Attempts to arrive at quantitative value assessments of information and information services have been less than successful. One of the major barriers to the collection of meaningful data concerning the value of information and information services is the conceptual difficulty of individuals in distinguishing between the value of information and the value of information services (King, et al., 1982). Mason (1979) states:

> The intrinsic value of information may be a valid measurement of the benefits of an information center service. However, this value is the value of the information service only if the information center is a monogamist and provides unquestioningly unique information.

Other problems include the nature of information, the subjective nature of value, the lack of an acceptable "unit" of measure for information, and the viewpoint from which the measurement is determined. As previously mentioned, one approach to measuring the value of information and information services is in terms of willingness to pay and time saved by researchers. This relies heavily on the ability of researchers to accurately access the value of information to themselves and, perhaps, to their organization.

Flowerdrew and Whitehead (n/d) have defined the problems associated with measuring the value of information and information services to a researcher's employer. First, there is the problem of overlap between the researcher's and the employer's values. Second, there is the problem of assessing the value of the researcher's time, particularly if substitute services are available

Kitchen (1989) expands the discussion stating that libraries, as part of the value-added process, are tools that ensure that users receive the information they need to function effectively and do so by providing assessed, relevant information products and services. To produce them, the library has added value to basis inputs by ensuring ease of use; relevance and ease of access to content; accuracy, adaptability, and flexibility to meet specific problems; and time and cost savings.

In attempting to develop a methodology for assessing the value of Canadian Federal libraries in economic terms, Kitchen (1989) noted that, while agency personnel were personally supportive of library service, they were skeptical of the value of any attempts at evaluation. They questioned the utility of such an exercise and pointed out that the results were not only unlikely to receive consideration, but could also be disregarded completely if political or internal considerations so dictated.

Information and R&D

The ability of engineers and scientists to identify, acquire, and utilize information is of paramount importance to the efficiency of the R&D process. Testimony to the central role of STI in the R&D process is found in numerous studies. These studies show, among other things, that engineers and scientists devote more time, on the average, to the communication of STI than to any other scientific or technical activity. A number of studies have found strong relationships between the communication of STI and technical performance at both the individual and group level. Thus, we conclude from a review of the available literature that the communication of STI is an essential element in achieving high R&D productivity.

In this paper, the R&D process has been simplified into two phases: idea formulation and problem solving. The literature indicates that STI **external** to the organization plays a predominant role in the idea formulation, while STI **internal** to the organization plays the more important role in problem solving (Dewhirst, et al., 1978). The implication for R&D managers, therefore, is to ensure a sufficient amount and variety of external contacts to foster "quality" idea formulation. This recommendation is supported by Project Sappho (1972) which reported that "one of the distinguishing characteristics of unsuccessful innovations was the poor utilization of external sources in idea formulation" and by Allen (1977) who found a strong positive correlation between the use of external sources and the technical quality of engineering proposals. This recognition appears to have implications for those who provide information services.

Problem solving differs most significantly from idea formulation in that greater emphasis is placed on the deliberate search for information (Rothwell and Robertson, 1973). As might be expected from groups of individuals assembled explicitly to solve problems that are frequently of a proprietary nature, the information sources of greatest value are those internal to the organization. Further, as Allen (1977) points out, the technical report plays a significant role as a source of internal information.

Allen's (1977) findings also reveal an interesting relationship between the frequency of information (channel) use and information (channel) performance, which leads us to conclude the existence of a relationship between the "cost" and "efficiency" of information. Gerstberger and Allen (1968), in their study of engineers and choice of an information channel, note:

Engineers, in selecting among information channels, act in a manner which is intended not to maximize gain, but, rather, to minimize loss. The loss to be minimized is the cost in terms of effort, either physical or psychological, which must be expended in order to gain access to an information channel.

Their behavior appears to follow a "law of least effort" (Zipf, 1949). According to this law, individuals, when choosing among several paths to a goal, will base their decision upon the single criterion of "least average rate of probable work."

According to Gerstenberger and Allen (1968), engineers appear to be governed or influenced by a principle closely related to this law. They attempt to minimize effort in terms of work required to gain access to an information channel. Perceived accessibility appears to be the primary determinant in an engineer's selection of an information source. This may help explain the relationship between **internal** sources and problem solving and also supports our earlier statement that value is subjective and user driven. Further, if "effort" is perceived to be a "cost" associated with information, its value and use, then it is possible that psychological "cost," the fear of revealing one's "lack of knowledge," may also influence information channel selection and usage.

Finally, the implications of this finding are very important to R&D managers and to those who provide information services. Improved quality or perceived performance of an information channel will not, in and of itself, lead to increased use of that service. Engineers will simply not be attracted to an information system by improving the quality and/or quantity of the information contained therein -- quite the contrary. Investments in an information system will, for the most part, be wasted unless the system is made more accessible to the user.

External information enters an organization in a number of ways. Of particular importance is the role played by "technological gatekeepers." These gatekeepers not only enjoy an especially high number of external information contacts (Allen, 1970; Holland, 1972), but they also are most frequently cited as choices for technical discussions, as well as consistently being the sources of the best technical ideas within the R&D group (Allen, 1977). It is the role of the technological gatekeeper to link **external** information channels, which are important to idea formulation, with **internal** information channels, which are highly crucial to problem solving. The role of the technological gatekeeper in the communication of STI is well established in the literature (Keller, et al., 1976).

In terms of external information, the technological gatekeeper reads far more, attends more conferences, and has personal contact with more individuals, inside and outside of the organization, than do non gatekeepers (Allen, 1977). In addition, technological gatekeepers have higher credibility and seem to be better at connecting seemingly unrelated information (Holland, 1972). Thus, the technological gatekeeper serves as a link between the organization and the external world.

Internally, technological gatekeepers serve as nodes in an organization's communications network. They are linked informally to other gatekeepers and they are linked to groups of non gatekeepers within the organization (Allen, 1977).

Information, therefore, entering an organization by way of a gatekeeper is circulated through the gatekeeper network to non gatekeepers and is eventually circulated throughout the organization. This role of the gatekeeper as an information moderator has been referred to as a two-step process of information acquisition and dissemination (Allen, 1977).

Information and U.S. Aerospace Engineers and Scientists

The aerospace industry continues to be the leading positive contributor to the U.S. balance of trade among all merchandise industries. According to the U.S. Department of Commerce (1988), the U.S. aerospace industry can look forward to the next five years with optimism. At the same time, international industrial alliances will result in a more rapid diffusion of technology, increasing the pressure on the U.S. aerospace industry to push forward with new technological developments.

In terms of empirically derived data, very little is known about the diffusion of innovation in the aerospace industry both in terms of the channels used to communicate the ideas and the information-gathering habits and practices of the members of the social system (i.e., aeronautical engineers and scientists). Most of the channel studies, such as the work by Gilmore, et al., (1967) and Archer (1962), have been concerned with the transfer of aerospace technology to non-aerospace industries.

Most of the studies involving aeronautical engineers and scientists, such as the work by McCullough, et al., (1982) and Pinelli, et al., (1982), have been limited to the use of NASA STI products and services and have not been concerned with their information-gathering habits and practices. Although researchers such as Davis (1975) and Spretnak (1982) have investigated the importance of technical communications to engineers, it is not possible to determine from the published results if the study participants included aeronautical engineers and scientists. It is likely that an understanding of the process by which innovation in the aerospace industry is communicated through certain channels over time among the members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of U.S. aeronautical engineers and scientists.

My colleagues and I have undertaken such a project. In 1988, we began the **Knowledge Diffusion Project** which involves determining the information-seeking habits and practices of U.S. aerospace engineers and scientists. One goal of the Project is to collect similar data from aerospace engineers and scientists in specific European countries and to compare/contrast these data with those collected in the U.S. Since little empirical knowledge exists regarding the information-seeking habits and practices of U.S. aerospace engineers and scientists, we began the project with an exploratory study designed to investigate the technical communications practices of U.S. aerospace engineers and scientists (Pinelli, et al., February 1989).

The results of the exploratory study were analyzed in terms of management and nonmanagement responses (Pinelli, et al., August 1989) and in terms of profit and nonprofit management responses (Pinelli, et al., October 1989). The remainder of our paper is devoted to a presentation of selected results from the management and nonmanagement analysis of the exploratory study data.

The Importance of Technical Communications

To determine the importance of technical communications in aerospace, survey respondents were asked to indicate the importance of communicating technical information effectively, the number of hours spent each week communicating technical information to others, and the number of hours spent each week working with technical communications received from others. Approximately 99 percent of the managers and nonmanagers surveyed (Table 1) indicate that the ability to communicate technical information effectively is important. Less than 1.0 percent indicate that this ability is not at all important.

Table 1. Importance of Technical Communications

How Important	Managers		Nonmanagers	
	No.	%	No.	%
Very	129	89.6	411	89.8
Somewhat	14	9.7	45	9.8
Not at all	1	0.7	2	0.4
Total	144	100.00	458	100.0

Managers spend an average of 13.6 hours per week communicating technical information to others (Table 2), and nonmanagers spend an average of 14.0 hours per week. Based on a 40-hour work week, both groups spend approximately 35 percent of their work week communicating technical information to others.

Table 2. Time Spent Communicating Technical Information to Others

Time Spent Per Week, Hour	Managers		Nonmanagers	
	No.	%	No.	%
5 or less	22	15.6	79	17.7
6 to 10	48	34.1	140	30.9
11 to 20	58	41.1	179	39.5
21 or more	13	9.2	55	11.9
Total	141	100.0	453	100.0
Mean	13.6		14.0	

Managers and nonmanagers spend approximately 13 hours a week working with technical communications received from others (Table 3), which is approximately 31 percent of their 40-hour work week.

Table 3. Time Spent Working With Technical Information Received From Others

Time Spent Per Week, Hour	Managers		Nonmanagers	
	No.	%	No.	%
5 or less	14	9.9	111	24.6
6 to 10	65	46.2	156	34.3
11 to 20	54	38.3	143	31.5
21 or more	8	5.6	44	9.6
Total	141	100.0	454	100.0
Mean	13.0		12.5	

Considering both the time spent working on the preparation of technical information and the time spent working with technical information received from others, communicating technical information takes up approximately 66 percent of the managers' and nonmanagers' 40-hour work week.

The Use and Production of Technical Communications

Survey respondents were asked to indicate the amount and type of technical information products they produced and used as well as the sources of help they sought in solving technical problems.

Memos, letters, and audio visual (A/V) materials are the technical information products most frequently produced by both managers and nonmanagers (Table 4). On the average, managers produced 49 memos,

Table 4. Production of Technical Information Products

Products	6-month average	
	Managers	Nonmanagers
Letters	*30.5	19.6
Memos	*49.0	22.6
Technical reports-Government	*2.1	1.4
Technical reports-Other	1.8	1.9
Proposals	*2.1	1.6
Technical manuals	0.3	0.3
Computer program documentation	0.5	*1.6
Journal articles	0.3	0.4
Conference/Meeting papers	*1.5	0.9
Trade/Promotional literature	*1.5	0.9
Press releases	*0.4	0.2
Drawings/Specifications	2.1	3.6
Speeches	*3.6	1.8
Audio/Visual materials	*9.6	5.6

* Differences between managers and nonmanagers are significant at $p < 0.05$.

30.5 letters, and 9.6 A/V materials in a 6-month period. On the average, nonmanagers produced 22.6 memos, 19.6 letters, and 5.6 A/V materials. Based on average production, a list of the five technical information products most frequently produced by managers and nonmanagers follows:

Most Frequently Produced By Managers	Most Frequently Produced By Nonmanagers
Memos	Memos
Letters	Letters
A/V materials	A/V materials
Speeches	Drawing/Specifications
*Government technical reports, Proposals, and Drawing/Specifications	Other technical reports

*indicates a tie for these three products

Memos, letters, trade/promotional literature, and journal articles are the technical information products most frequently used by both managers and nonmanagers (Table 5).

Table 5. Use of Technical Information Products

Products	1-month average	
	Managers	Nonmanagers
Letters	*30.8	12.3
Memos	*38.7	19.8
Technical reports-Government	4.3	4.2
Technical reports-Other	*4.9	1.1
Proposals	*2.5	4.4
Technical manuals	1.1	*2.6
Computer program documentation	2.2	*3.2
Journal articles	5.8	*7.1
Conference/Meeting papers	4.0	4.4
Trade/Promotional literature	7.2	5.3
Drawings/Specifications	*4.6	9.0
Audio/Visual materials	*6.8	5.2

* Differences between managers and nonmanagers are significant at $p < 0.05$.

On the average, managers used 38.7 memos, 30.8 letters, 7.2 trade/promotional literature, and 6.8 A/V materials in a 1-month period. Nonmanagers used 19.8 memos, 12.3 letters, 9.0 drawings/specifications, and 7.1 journal articles in a 1-month period. Based on average use, a list of the five technical information products most frequently used follows:

Most Frequently Used By Managers	Most Frequently Used By Nonmanagers
Memos	Memos
Letters	Letters
Trade/Promotional literature	Drawing/Specifications
A/V materials	Journal articles
Journal articles	Trade/Promotional literature

Managers and nonmanagers produce various types of technical information in the performance of their duties (Table 6).

Table 6. Types of Technical Information Produc
[n = 144 for managers; n = 456 for nonmanagers]

Types of Technical Information	Managers		Nonmanagers	
	No.	%	No.	%
Scientific and technical information	126	87.5	427	*93.6
Experimental techniques	47	32.6	222	*48.7
Codes of standards and practices	34	23.6	92	20.2
Design procedures and methods	63	44.1	219	48.1
Computer programs	55	38.2	288	*63.2
Government rules and regulations	25	17.5	66	14.5
In-house technical data	124	86.1	385	84.4
Product and performance characteristics	83	57.6	266	58.5
Economic information	71	*49.3	93	20.4
Technical specifications	82	56.9	276	60.5
Patents	26	18.1	82	18.0

* Differences between managers and nonmanagers are significant at $p < 0.05$.

A list of the five most frequently produced types of technical information follows:

Most Frequently Produced By Managers	Most Frequently Produced By Nonmanagers
Scientific and technical information	Scientific and technical information
In-house technical data	In-house technical data
Product and performance characteristics	Computer programs
Technical specifications	Technical specifications
Economic information	Product and performance characteristics

Managers and nonmanagers use various types of technical information in the performance of their duties (Table 7).

Table 7. Types of Technical Information Used
[n = 144 for managers; n = 456 for nonmanagers]

Types of Technical Information	Managers No.	Managers %	Nonmanagers No.	Nonmanagers %
Scientific and technical information	139	96.5	443	97.1
Experimental techniques	73	50.7	290	*63.7
Codes of standards and practices	69	47.9	217	47.7
Design procedures and methods	78	54.2	258	56.7
Computer programs	100	69.4	385	*84.4
Government rules and regulations	117	*81.3	313	68.8
In-house technical data	136	94.4	407	89.3
Product and performance characteristics	103	71.5	331	72.6
Economic information	77	*53.5	138	30.3
Technical specifications	112	77.8	350	76.8
Patents	24	16.7	60	13.2

* Differences between managers and nonmanagers are significant at $p < 0.05$.

A list of the five most frequently used kinds of technical information follows:

Most Frequently Used By Managers	Most Frequently Used By Nonmanagers
Scientific and technical information	Scientific and technical information
In-house technical data	In-house technical data
Government rules and regulations	Computer programs
Technical specifications	Technical specifications
Product and performance characteristics	Product and performance characteristics

As shown in Table 8, managers and nonmanagers use a variety of information sources when solving technical problems.

The "always" and "usually" responses, which appear as percentages in Table 8, were combined to form the following list of information sources used by managers and nonmanagers to solve technical problems, given in decreasing order of frequency.

Table 8. Sources of Technical Information Used to Solve Technical Problems

Sources of Technical Information	Number of Respondents	Percent of Respondents			
		Always	Usually	Sometimes	Never
		Managers			
Personal knowledge	142	35.9	48.6	15.5	0.0
Informal discussions with colleagues	143	16.8	59.4	23.8	0.0
Discussions with supervisors	141	6.4	27.7	55.3	10.6
Discussions with experts in organization	144	21.5	51.4	26.4	0.7
Discussions with experts outside of organization	*143	4.2	25.2	66.4	4.2
Technical reports-Government	143	2.8	20.3	69.2	7.7
Technical reports-Other	144	2.8	22.9	70.8	3.5
Professional journals/conference meeting papers	143	4.9	23.1	55.9	16.1
Textbooks	144	1.4	21.5	63.9	13.2
Handbooks and standards	140	2.9	14.3	67.9	15.0
Technical information sources, such as on-line data bases, indexing and abstracting guides, CD-ROM, and current awareness tools	139	0	6.5	43.9	49.6
Librarians/technical information specialists	141	0	9.9	65.2	24.8
		Nonmanagers			
Personal knowledge	456	44.5	45.4	10.1	0.0
Informal discussions with colleagues	456	21.1	56.6	21.9	0.4
Discussions with supervisors	451	11.3	37.5	45.2	6.0
Discussions with experts in organization	453	17.9	50.6	30.2	1.3
Discussions with experts outside of organization	*455	6.8	17.4	66.2	9.7
Technical reports-Government	*455	6.8	29.7	58.0	5.5
Technical reports-Other	453	6.6	31.6	58.7	3.1
Professional journals/conference meeting papers	*452	10.6	26.5	52.7	10.2
Textbooks	*454	11.0	33.7	51.1	4.2
Handbooks and standards	*450	7.8	31.8	52.4	8.0
Technical information sources, such as on-line data bases, indexing and abstracting guides, CD-ROM, and current awareness tools	444	1.6	7.0	45.3	46.2
Librarians/technical information specialists	454	3.3	11.9	66.3	18.5

* Differences between managers and nonmanagers are significant at $p < 0.05$.

Information Sources Used By Managers to Solve Technical Problems

Sources	Percent of Cases
1. Personal knowledge	84.5
2. Informal discussion with colleagues	76.2
3. Discussions with experts within the organization	72.9
4. Discussions with supervisor	34.1
5. Discussions with experts outside of your organization	**29.4**
6. Journals and conference/meeting papers	28.0
7. Technical reports - other	25.7
8. Technical reports - government	23.1
9. Textbooks	22.9
10. Handbooks and standards	17.2
11. Librarians/technical information specialists	9.9
12. Technical information sources such as on-line databases	6.5

Information Sources Used By Nonmanagers to Solve Technical Problems

Sources	Percent of Cases
1. Personal knowledge	89.9
2. Informal discussion with colleagues	77.7
3. Discussions with experts within the organization	**68.5**
4. Discussions with supervisor	48.8
5. Textbooks	44.7
6. Handbooks and standards	39.6
7. Technical reports - other	38.2
8. Journals and conference/meeting papers	37.1
9. Technical reports - government	36.5
10. Discussions with experts outside of your organization	24.2
11. Librarians/technical information specialists	15.2
12. Technical information sources such as on-line databases	8.6

The managers and nonmanagers in this study display a preference for personalized, informal information sources. Both groups identified an informal search for information using personal contacts as their primary method, followed by the use of formal information sources. Only after they have completed an informal search, followed by the use of formal information sources, do they turn to librarians and technical information specialists for assistance.

Of particular significance, however, is the use of experts outside the organization by the two groups. Managers turn to experts outside the organization more frequently than do nonmanagers. Statistically, managers are more likely to use this information source than nonmanagers. On the other hand, nonmanagers are more likely than managers to use discussions with supervisors, government technical reports, journal articles and meeting papers, textbooks, and handbooks and standards.

Use of Libraries, Technical Information Centers, and On-Line Databases

To determine the use of libraries, technical information centers, and on-line databases, survey respondents were asked three questions. They were asked to indicate how often they used a library or technical information center, their use of on-line databases, and how they search the databases.

Approximately 92 percent of the managers and 95 percent of the nonmanagers use a library or technical information center (Table 9). The frequency rates vary

Table 9. Use of Library or Technical Information Center

Frequency of Use	Managers		Nonmanagers	
	No.	%	No.	%
Daily	1	0.7	11	2.4
Two to six times a week	9	6.3	50	11.0
Once a week	17	11.7	72	15.8
Two to three times a month	24	16.7	92	*20.2
Once a month	22	15.3	80	17.5
Less than once a month	59	*41.0	127	27.8
Do not use	12	8.3	24	5.3
Total	144	100.0	456	100.0

* Differences between managers and nonmanagers are significant at $p < 0.05$.

among managers and nonmanagers, however, with approximately 19 percent of the managers using a library or technical information center one or more times a week and approximately 29 percent of the nonmanagers using a library or technical information center one or more times a week. Thirty-two percent of the managers and approximately 38 percent of the nonmanagers use a library or technical information center one or more times a month. Forty-one percent of the managers and approximately 28 percent of the nonmanagers use a library or technical information center less than once a month.

Fewer than one-third (31.2 percent) of the managers and fewer than one-half (48.1 percent) of the nonmanagers use on-line (electronic) databases (Table 10).

Table 10. Use of Electronic Databases

Use	Managers		Nonmanagers	
	No.	%	No.	%
Yes	45	31.2	219	*48.1
No	99	68.8	236	51.9
Total	144	100.0	455	100.0

* Differences between managers and nonmanagers are significant at $p < 0.05$.

Of those respondents who use databases, none of the managers and approximately 8 percent of the nonmanagers do all of their own searches (Table 11).

Table 11. How Electronic Databases Are Searched

How Searched	Managers		Nonmanagers	
	No.	%	No.	%
Do all searches yourself	0	0.0	18	* 8.3
Do most searches yourself	4	9.4	38	*17.5
Do half by yourself and half through an intermediary (e.g. librarian)	5	11.6	27	12.4
Do most searches through an intermediary (e.g. librarian)	17	39.5	75	34.6
Do all searches through an intermediary	17	39.5	59	27.2
Total	43	100.0	217	100.0

* Differences between managers and nonmanagers are significant at $p < 0.05$.

Fewer than 10 percent of the managers and approximately 18 percent of the nonmanagers do most of their own database searches. Approximately 12 percent of the managers and nonmanagers do one-half of their searches and have the other one-half done by an intermediary. Approximately 79 percent of the managers use an intermediary to do most or all of their (electronic) database searches, and about 62 percent of the nonmanagers use an intermediary to do most or all of their searches.

Concluding Remarks

R&D is information dependent. Scientific and technical information (STI), which is central to the function and success of R&D, has intrinsic value; STI helps engineers and scientists perform better research, STI saves them time and effort, and helps managers make better decisions. STI is also related to productivity and economic competitiveness. Although information is considered to have value, there is no universal or standard "measurement" by which its value can be assessed. Just as beauty lies in the eye of the beholder, so too does the value of information lie in the mind of the user. Perhaps the greater issue lies in the recognition by R&D managers that information is inseparable from R&D, and that within the R&D process, knowledge transfer and utilization should be accorded treatment equal to that of knowledge production. Information external to an organization is essential, and some would argue, crucial to successful R&D. But herein lies the problem, organizations have a tendency to isolate themselves from the outside world and to erect barriers to communications with the external environment. This isolation is due in part to the need for organizations to exercise control over those situations in which they interact with the "outside." This is the nature of organizations and, with time, becomes part of their "culture." The danger for an R&D organization is to become completely closed to the outside and to external information. R&D managers must realize that information external to an organization is a resource and should be treated as such and that they have a very direct influence upon the use of such information by the engineers and scientists within their organizations. However, as Wolek, who is quoted by Schuelke (1977), states:

> Most managers are unable to represent the importance of STI to their people and they resist including the communication of information in their management responsibilities because engineers and scientists with whom they work have not requested them.

Further, Holland, Stead, and Leibrock (1976) state that there is a great need for the management of information resources by R&D managers especially in times of "technical uncertainty." Unfortunately, they conclude, R&D managers usually reduce information budgets during periods of technical uncertainty since such periods often coincide with economic constraints. Empirically, very little is known about the information-seeking habits and practices of aerospace engineers and scientists. Even less is known about the flow of STI in the aerospace industry and its role in the R&D process. Greater knowledge and understanding should contribute to increasing productivity, innovation, and to maintaining and improving the professional competency of aerospace engineers and scientists.

References

Allen, Thomas J. *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization.* (Cambridge, MA: MIT Press, 1977.)

Allen, Thomas J. "Roles in Technical Communication Networks." in *Communication Among Scientists and Engineers.* Carnot E. Nelson and Donald K. Pollock eds. (Lexington, MA: D.C. Heath, 1970), 191-208.

Archer, John F. *The Diffusion of Space Technology By Means of Technical Publications: A Report Based on the Distribution, Use, and Effectiveness of "Selected Welding Techniques."* Boston: American Academy of Arts and Sciences, November 1964. 33 p. (Available from: NTIS Springfield, VA; 70N76955.)

Berg, Sanford V. "An Economic Analysis of the Demand for Scientific Journals." *Journal of the American Society for Information Science* 23:1 (January/February 1972): 23-29.

Davis, Richard M. "How Important is Technical Writing? -- A Survey of the Opinions of Successful Engineers." *Technical Writing Teacher* 4:3 (Spring 1977): 83-88.

Dewhirst, H. Dudley; Richard D. Avery; and Edward M. Brown. "Satisfaction and Performance in Research and Development Tasks as Related to Information Accessibility." *IEEE Transactions on Engineering Management* EM-26:1 (August 1979): 58-63.

Fischer, William A. "Scientific and Technical Information and the Performance of R&D Groups." in *Management of Research and Innovation.* Burton V. Dean and Joel L. Goldhar eds. (NY: North-Holland Publishing Company, 1980), 67-89.

Flowerdew, Anthony D.J. and C.M.E. Whitehead. *Cost-Effectiveness and Cost/Benefit Analysis in Information Service.* (London: London School of Economics, n/d.)

Gerstberger, Peter G. and Thomas J. Allen. "Criteria Used By Research and Development Engineers in the Selection of an Information Source," *Journal of Applied Psychology* 52:4 (August 1968): 272-279.

Gilmore, John S. et al., *The Channels of Technology Acquisition in Commercial Firms and the NASA Dissemination Program.* Denver, CO: Denver Research Institute, June 1967. 107 p. (Available from: NTIS Springfield, VA; N67-31477.)

Hawgood, John and Robert Morley. *Project for Evaluating the Benefits from University Libraries.* Durham, NC: Durham University, 1969.

Holland, Winford E. "Characteristics of Individuals with High Information Potential in Government Research and Development Organizations," *IEEE Transactions on Engineering Management* EM-19:2 (May 1972): 38-44.

Holland, Winford, E.; Bette Ann Stead; and Robert C. Leibrock. "Information Channel/Source Selection as a Correlate of Technical Uncertainty in a Research and Development Organization," *IEEE Transactions on Engineering Management* EM-23:4 (November 1976): 163-167.

Holmfeld, John D. *Communication Behavior of Scientists and Engineers.* Ph.D. Diss., Case Western Reserve University, 1970. 70-25874.

Joenk, Rudy J. "Engineering Text for Engineers." Chapter 15 in *Technology of Text: Vol. II Principles for Structuring, Designing, and Displaying Text.* David H. Jonassen ed. (Englewood Cliffs, NJ: Educational Technology Publications, 1985), 346-369.

Keller, R.T.; M. Szilagyi; and W.E. Holland. "Boundary-Spanning Activity and Employee Relations: An Empirical Investigation," *Human Relations* 29 (1976): 699-710.

King, Donald W.; Jose-Marie Griffiths; Nancy K. Roderer; and Robert R.V. Wiederkehr. *Value of the Energy DataBase.* Rockville, MD: King Research, Inc., March 31, 1982. 79 p. (Available from: NTIS Springfield, VA; PB-260 374.)

Kitchen, Paul and Associates. *A Review of the Feasibility of Developing a Methodology to Demonstrate the Value of Canadian Federal Libraries in Economic Terms.* Canada: Paul Kitchen and Associates, March 1989.

Krulee, G.K. and E.B. Nadler. "Studies of Education for Science and Engineering: Student Values and Curriculum Choice," *IRE Transactions on Engineering Management* 7:4 (June 1960): 157-158.

Mason, R.M. *A Study of the Perceived Benefits of Information Analysis.* Atlanta: Metrics, Inc., March 1979.

Mason, R.M. and P.G. Sassone. "A Lower Bound Cost Benefit Model for Information Processing for Information Services," *Information Processing and Management* 14 (1978): 71-83.

McCullough, Robert A.; Thomas E. Pinelli; Douglas D. Pilley; and Freda F. Stohrer. *A Review and Evaluation of the Langley Research Center's Scientific and Technical Information Program. Results of Phase VI. The Technical Report: A Survey and Analysis.* Washington, DC: National Aeronautics and Space Administration. NASA TM-83269. April 1982. 136 p. (Available from: NTIS, Springfield, VA; 87N70843.)

National Academy of Sciences, Committee on Scientific and Technical Communication. *Report of a Task Group on the Economics of Primary Publication.* Washington, DC: National Academy of Sciences, 1970.

Pinelli, Thomas E.; Myron Glassman; and Virginia M. Cordle. *Survey of Reader Preferences Concerning the Format of NASA Technical Reports.* Washington, DC: National Aeronautics and Space Administration. NASA TM-84502. August 1982. 86 p. (Available from: NTIS, Springfield, VA; 82N34300.)

Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. *Technical Communications in Aeronautics: Results of an Exploratory Study.* Washington, DC: National Aeronautics and Space Administration. NASA TM-101534, Part 1, February 1989. 106 p. (Available from NTIS, Springfield, VA; 89N26772.)

Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. *Technical Communications in Aeronautics: Results of an Exploratory Study.* Washington, DC: National Aeronautics and Space Administration. NASA TM-101534, Part 2, February 1989. 84 p. (Available from NTIS, Springfield, VA; 89N26773.)

Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. *Technical Communications in Aeronautics: Results of an Exploratory Study -- An Analysis of Managers' and Nonmanagers' Responses.* Washington, DC: National Aeronautics and Space Administration. NASA TM-101625. August 1989. 58 p. (Available from NTIS, Springfield, VA; 90N11647.)

Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. *Technical Communications in Aeronautics: Results of an Exploratory Study -- An Analysis of Profit Managers' and Nonprofit Managers' Responses.* Washington, DC: National Aeronautics and Space Administration. NASA TM-101626. October 1989. 71 p. (Available from NTIS, Springfield, VA.)

Roderer, Nancy K.; Donald W. King; and Sandra E. Brouard. *Use and Value of Defense Technical Information Center Products and Services.* Rockville, MD: King Research, Inc., June 1983. (Available from: NTIS Springfield, VA; AD-A130 805.)

Rothwell, R. and A.B. Robertson. "The Role of Communications in Technological Innovation," *Research Policy* 2 (1973): 204-225.

Schuelke, L. David. *Innovation, Communication and the Management of Technology Transfer.* WorldTech Report No.4 January 1977. St. Paul, MN: Control Data TechNotec, Inc., 1977.

Science Policy Research Unit, University of Sussex. *Success and Failure in Industrial Innovation.* London: Centre for the Study of Industrial Innovation, 1972.

Shapley, Deborah and Rustom, Roy. *Lost at the Frontier: U.S. Science and Technology Policy Adrift.* (Philadelphia: ISI Press, 1985.)

Spretnak, Charlene M. "A Survey of the Frequency and Importance of Technical Communication in an Engineering Career," *Technical Writing Teacher* 9:3 (Spring 1972): 133-136.

Taylor, Robert S. *Value-Added Processes in Information Systems.* (Norwood, NJ: Ablex Publishing, 1986.)

U.S. Department of Commerce. *1989 U.S. Industrial Outlook.* Washington, DC: Government Printing Office, January 1989.

Willis, G. and C. Oldman. "An Examination of Cost/Benefit Approaches to the Evaluation of Library and Information Services," in *Evaluation and Scientific Management of Libraries and Information Centers.* F.W. Lancaster and C.W. Cleverdon eds. (Leyden: Noordhoff, 1977.)

Wolfe, J.L. et al., *The Economics of Technical Information Services: A Study of Cost-Effectiveness.* Edinburgh: University of Edinburgh, 1972.

Zipf, Geo K. *Human Behavior and the Principle of Least Effort.* (Cambridge, MA: Addison-Wesley, 1949.)

Thomas E. Pinelli
Mail Stop 180A
NASA Langley Research Center
Hampton, VA 23665-5225
USA
(804) 864-2491
FAX (804) 864-3161